

TITLE: METHOD AND APPARATUS FOR HYDROGENATING HYDROCARBON FUELS

5 This is a continuation-in-part of US Patent Application 10/287,720, filed on Nov. 05, 2002, which is a division of US Patent Application serial number 09/620,250 filed on July 20, 2000.

FIELD OF THE INVENTION

10 This invention relates to the production of hydrogen gas from a catalytic reaction of aluminum and water, and the mixing of the hydrogen gas into a hydrocarbon fuel to improve the combustion efficiency of the fuel.

BACKGROUND OF THE INVENTION

15 Generally speaking, it is known that under certain conditions, aluminum reacts with water to generate hydrogen and heat. It is also known, however, that this type of reaction is not sustainable at ambient temperature. It is believed that a protective oxide layer forms on a metal surface in contact with water at ambient temperature and hampers the reaction. Therefore, it has been accepted by those skilled in the art that the
20 use of aluminum in a reaction with water to generate heat and hydrogen gas requires that the protective oxide layer is efficiently and continuously removed, and that the reaction is kept at an elevated temperature.

A number of hydrogen generators have been developed in the past. The following patent documents constitute a good inventory of the devices and
25 methods of the prior art in the field of hydrogen gas generation using the reaction of aluminum or alloys of aluminum with water.

US **909,536** issued on Jan. 12, 1909, and US **934,036** issued on Sept. 14, 1909, both issued to G. F. Brindley et al. These documents disclose several compositions for generating hydrogen. The compositions comprise any metal which can form an hydroxide when it is brought into contact with a solution of a suitable hydroxide. For example, aluminum is reacted with sodium hydroxide to release hydrogen and produce sodium aluminate.

US **2,721,789**, issued on Oct. 25, 1955 to Q.C. Gill. This document discloses the structure of an hydrogen generator for reacting water with a measured dry charge of aluminum particles and flakes of sodium hydroxide. The reaction releases hydrogen gas and produces sodium aluminate.

US **3,554,707** issued on Jan. 12, 1971 to W.A. Holmes et al. This document discloses a gas generator having bellows to raise or lower the level of water in response to the pressure inside the generator. As the level of water drops, the contact surface between the fuel cartridge and the water is lost and the reaction is terminated.

US **3,957,483** issued on May 18, 1976 to M. Suzuki. This patent discloses a magnesium composition which produces hydrogen upon contact with water. The preferred magnesium composition comprises magnesium, and one or more metals selected from the group consisting of iron, zinc, chromium, aluminum and manganese.

US **3,975,913** issued on Aug. 24, 1976 to D.C. Erickson. This document discloses a hydrogen generator wherein molten aluminum is reacted with water. The generator is kept at a very high temperature to keep the metal in a molten condition.

US 4,643,166 issued on Feb. 17, 1987, and

US 4,730,601 issued on Mar. 15, 1988 both to H.D. Hubele et al. These documents disclose the structure of a fuel cell for producing heat energy and hydrogen gas. The device has a reaction chamber containing a fuel composition that is reactive with water. The fuel composition includes a main fuel part of magnesium and aluminum in a molar ratio of 1:2, and the second part is composed of lithium hydride, magnesium and aluminum in equal molar ratio.

US 4,670,018 issued on June 2, 1987, and

US 4,769,044 issued on Sept. 6, 1988, both to J.H. Cornwell. These documents describe a log made of compressed wood waste and paper. The log is coated with aluminum particles. Upon burning, the aluminum particles react with moisture in the log to emit heat due to the generation of hydrogen gas.

US 4,752,463 issued on June 21, 1988 to K. Nagira et al. This document discloses an alloy which reacts with water for producing hydrogen gas. The alloy material comprises essentially aluminum and 5 to 50% tin.

US 5,143,047 issued on Sept. 1, 1992 to W.W. Lee. This document discloses an apparatus and a method for generating steam and hydrogen gas. In this apparatus, an aluminum or aluminum alloy powder is reacted with water to generate hydrogen gas. An electric power source is used to start the reaction. The electric power source is used to explode an aluminum conductor and to disperse pieces of molten aluminum into a mixture of water and aluminum powder. A heat exchanger is provided to extract useful heat.

US 5,867,978 issued on Feb. 9, 1999 to M. Klanchar et al. This document discloses another hydrogen gas generator using a charge of fuel selected from the group consisting of lithium, alloys of lithium and aluminum. The charge of fuel is molten and mixed with water to generate hydrogen gas.

5 JP 401,208,301 issued to Mito on Aug. 22, 1989. This document discloses a process for producing hydrogen. Aluminum is reacted with water under an inactive gas or a vacuum to produce hydrogen gas.

10 CA 2,225,978 published on June 29, 1999 by J. H. Checketts. This patent application discloses a hydrogen generation system wherein a coating on reactive pellets is selectively removed to expose the reactive material to water for producing hydrogen gas on demand. In one embodiment, aluminum and sodium hydroxide are reacted with water to release hydrogen gas and produce sodium aluminate.

15 Various other processes to produce hydrogen gas have been described in the art, as reacting water with magnesium, sodium, potassium, lithium, calcium, iron, zinc or steel.

20 Although the hydrogen production processes of the prior art deserve undeniable merits, it is believed that the catalytic reaction of aluminum and water, using sodium hydroxide as the catalyst, to release hydrogen gas from water at room temperature has never been anticipated or observed and disclosed by prior inventors. It is also believed that the prior art is short of suggestion with regards to a hydrogen production process which can be readily used to hydrogenate the fuel of engines and burners.

25 As such, it will be appreciated that there continues to be a need for a production process and for an apparatus for generating hydrogen gas using

a simple and economical reaction which can be started at room temperature and carried out safely by ordinary persons not having a formal education in chemistry and chemical processes.

SUMMARY OF THE INVENTION

5 Broadly stated, the process for producing hydrogen gas according to the present invention consists of reacting aluminum with water in the presence of sodium hydroxide as a catalyst. This process is advantageous for being carried out at room temperature and for producing large quantities of heat and hydrogen gas at high purity. The process and apparatus are easily
10 connected to the fuel lines of engines and burners to hydrogenate petroleum fuels.

In a first aspect of the present invention, there is provided a process for hydrogenating a hydrocarbon fuel, comprising the steps of providing a receptacle; partly filling this receptacle with an aqueous solution
15 containing sodium hydroxide, and introducing aluminum in this aqueous solution, thereby producing hydrogen gas. The hydrogen gas is injected into a fuel line containing hydrocarbon fuel for hydrogenating the fuel and improving its combustion characteristics.

In a second aspect of the present invention, there is provided another
20 process for hydrogenating a hydrocarbon fuel. This second process comprises the steps of providing a receptacle and partly filling this receptacle with an aqueous solution containing sodium hydroxide. A hydrocarbon fuel is then introduced inside the receptacle atop the aqueous solution. Aluminum is introduced in the aqueous solution, thereby
25 producing hydrogen gas. The hydrogen gas is bubbled through the hydrocarbon fuel for hydrogenating the fuel.

In a third aspect of the present invention, there is provided an apparatus for hydrogenating a hydrocarbon fuel. This apparatus comprises broadly a receptacle and a conduit and control devices to introduce an aqueous solution in this receptacle and to maintain the solution at a specific level.

5 The apparatus also comprises an aluminum storage and delivery system to introduce aluminum inside the receptacle below the specific level. A fuel piping system is provided to introduce, to float and to circulate a hydrocarbon fuel inside the receptacle above the specific level. This apparatus is usable in a continuous process to hydrogenate a continuous
10 flow of hydrocarbon fuel to a large diesel engine or to the burners of an industrial boiler for examples.

The latter process and apparatus are also advantageous for cleaning the hydrogen gas of any water vapour and condensate as these impurities are
15 filtered out by the fuel layer. The hydrogen gas floating through the fuel layer is relatively clean.

Other advantages and novel features of the present invention will become apparent from the following detailed description of the preferred
20 embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the present invention selected by way of examples will now be described with reference to the accompanying drawings, in which:

25 **FIG. 1** is a side view of the preferred energy production apparatus, also referred to herein as the hydrogen generator;

FIG. 2 is a cross-section view of the energy production apparatus illustrating a mode of operation thereof when the fuel cartridge is entirely immersed in water;

5 **FIG. 3** is another cross-section view of the energy production apparatus with the fuel cartridge in a raised position when pressure inside the apparatus force the bellows of the apparatus to expand;

FIG. 4 illustrates yet another cross-section view of the energy production apparatus with the timer mechanism in an unlatched mode causing a spring to pull the cartridge out of the water;

10 **FIG. 5** is a schematic diagram of the preferred gas handling manifold and a burner plate mounted on the energy production apparatus;

FIG. 6 is a side view of the upper fuel support portion of the energy production apparatus;

15 **FIG. 7** illustrates a side view of a preferred burner plate and an optional heat storage device for use with the energy production apparatus;

FIG. 8 is a top view of the preferred timer mechanism for use with the energy production apparatus;

FIG. 9 is a partial cross-section view through the timer mechanism along line 9-9 in **FIG. 8.**;

20 **FIG. 10** illustrates a first arrangement for a fuel cartridge for use with the energy production apparatus;

FIG. 11 illustrates a second arrangement for a fuel unit for use with the energy production apparatus;

FIG. 12 illustrates one form for the fuel pellet for use with the energy production apparatus;

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FIG. 13 illustrates a third arrangement for a fuel unit for use with the energy production apparatus.

FIG. 14 illustrates a graph of temperature over time for a typical hydrogen gas production reaction;

10 **FIG. 15** illustrates a portable hydrogen generator according to the preferred embodiment of the present invention with a conduit to an internal combustion engine, wherein the hydrogen gas produced is injected into the fuel to the engine;

15 **FIG. 16** illustrates an hydrogen generator according to an alternate embodiment of the present invention wherein the hydrocarbon fuel is fed directly into the receptacle for the mixing of the hydrogen gas therewith.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

20 While this invention is susceptible of embodiments in many different forms, there is shown in the drawings and will be described in details herein a specific embodiment of the method and apparatus according to the present invention, with the understanding that the present disclosure is to

be considered as an example of the principles of the invention and is not intended to limit the invention to the embodiment illustrated.

5 The production of hydrogen gas according to the present invention is obtained by a reaction of aluminum with water in the presence of sodium hydroxide (NaOH) as a catalyst. The reaction produces a large amount of heat and hydrogen gas.

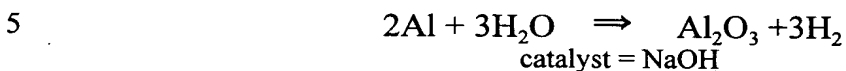
10 The catalyst is mixed with tap water in a proportion of about 225 g. per liter of water. In other words, the sodium hydroxide content of the catalytic solution is preferably about 18% by weight. The catalyst is not chemically consumed in the process.

15 The aluminum used in the reaction comprises aluminum foil, electrical wire, beverage cans and other similar aluminum waste. The intensity of the reaction depends upon the surface of contact between the aluminum and water. Aluminum foil for example reacts faster than a heavy gauge aluminum wire, and aluminum in a powdered form reacts instantly to produce hydrogen gas.

20 A series of eight experiments was carried out to measure the volume of hydrogen gas produced in a typical reaction. In these experiments, aluminum foil from Reynolds Aluminum Company of Canada was loosely crumpled and placed in a one litre plastic bottle containing 500 ml of catalytic solution. The bottle was quickly capped with a cover fitted with a tube which led to an inverted volumetric cylinder filled with water. The bottle was immersed in a water bath to prevent overheating.

25 The volume of water displaced by the gas produced was measured and corrected to a gas volume at standard temperature and pressure (STP).

Atmospheric pressure on that day was obtained from a local weather office. The corrected volume of gas produced was compared to the theoretical quantity of hydrogen gas, which would be obtained according to the equation,



These experiments were carried out at a room temperature of 21 °C and an atmospheric pressure of 758 mm of Hg. In all cases the reaction started in few seconds and continued for few minutes, until depletion of the aluminum foil. It was noticed that a typical reaction with less than 5 grams of loosely crumpled aluminum foil, is complete in less than 5 minutes. The results of these experiments are shown in **Table 1** below.

Table 1: Hydrogen Gas Production from Aluminum Foil

Exp. (#)	Al (g.)	H ₂ (l)	H ₂ (l) (STP)	H ₂ (l) Theoretical	Yield (%)	Deviation (+/- %)
1	2.08	2.94	2.71	2.59	104	2.6
2	2.03	2.85	2.62	2.53	104	2.6
3	2.21	3.05	2.81	2.75	102	2.5
4	2.16	2.9	2.67	2.69	99	2.6
5	2.2	3.04	2.8	2.74	102	2.5
6	2.21	3.04	2.8	2.76	102	2.5
7	0.73	1.03	0.94	0.91	103	2.4
8	0.83	1.15	1.05	1.03	102	2.2
Ave.					102	2.47

The results from **Table 1** show that the reaction is reproducible and produces stoichiometric quantities of hydrogen gas. The 102% average

yield of hydrogen gas is considered to be within the measurement uncertainty; however, there are at least two factors which might have contributed to a slightly higher hydrogen yield. Firstly, the volume of gas produced was corrected to STP. It is possible that the exhausted fume hood in which the experiments were carried out could have lowered the reaction pressure below the atmospheric pressure of 758 mm of Hg. This would have increased the observed value for the volume of gas produced. An exhaust bench typically runs at 1 inch or 2 inches of water pressure. At a maximum, this could have increased the measured volume by about 0.5%. Secondly, the water used was tap water in all cases, in which dissolved air may have been present. If any of this air had been released in the presence of the warm hydrogen gas, this would have increased the volume of gas measured. This would have affected the results by less than 1%. Since the results are within the measurement error, and quantification of these two sources of error would not significantly affect the results, no further experiment was carried out in this area.

The procedure used in the above experiments was repeated, with the exception that the tube leading from the top of the reaction bottle was connected to a gas sampling bag. Two samples of gas were obtained and analysed. The results are presented in **Table 2**.

Table 2: Gas Analysis

Sample	Hydrogen Concentration	Oxygen & Nitrogen
1	92 %	balance
2	98 %	balance

Table 2 shows that the purity of the hydrogen collected in the second sample was 98%. This is close to what was theoretically expected. The

lower 92% concentration observed in the first sample was probably due to the fact the system was not completely purged with hydrogen before the sample was taken. By the time the second sample was taken, most of the air had been purged from the tube and the reaction bottle.

5 Having explained the preferred method for producing hydrogen gas, the following disclosure and drawings describe a preferred apparatus for carrying out the method.

Referring firstly to **FIGS. 1 and 2**, an energy production apparatus according to the preferred embodiment of the present invention is illustrated therein. The energy production apparatus, also referred to herein as the hydrogen generator **20** is illustrated in these figures in its entirety. The hydrogen generator **20** uses water and aluminum particles as fuel, and sodium hydroxide (NaOH) as a catalyst and a surface conditioner to reduce the formation of oxide layers on the aluminum particles. The sodium hydroxide may be mixed or otherwise closely associated with the aluminum particles in a sufficient amount to ensure complete reaction of the aluminum particles with water in an energy production period. Further discussion on the incorporation of sodium hydroxide with the aluminum particles will be provided later, especially when making reference to **FIGS. 10-13**.

The sodium hydroxide may also be pre-mixed with water to form a catalytic aqueous solution in which aluminum is introduced to produced hydrogen gas on demand. In that case, only water and aluminum are added to sustain a reaction.

The hydrogen generator **20** comprises firstly a receptacle **22** having a first closable fill opening **24**, a sight glass **26** for monitoring the level of water therein, and a second closable larger opening **28** in a central upper region thereof. The receptacle **22** also preferably has a clean out bung **30** through
5 its bottom surface to facilitate the periodic removal of the reaction byproducts such as alumina.

In use, the receptacle **22** is filled with water **32**, to a level of between half and three-quarter of its capacity. A fuel cartridge **34** hanging from a vertical tube **36** is immersed into the water **32** for causing a chemical
10 reaction to occur with the water, and for producing heat and hydrogen gas.

The fuel cartridge **34** is supported in a perforated basket **38** affixed to the vertical tube **36**. The vertical tube **36** is connected to a gas handling manifold **40** mounted above the receptacle **22**, and has a series of holes **42** therein for admitting the hydrogen gas into the gas handling manifold **40**.

15 An annular cap **44** is also provided for mounting over the upper central opening **28** of the receptacle. Several clasps **46** are provided around the annular cap **44** for securing the annular cap **44** in a sealing manner to the upper central opening **28**. It will be appreciated that the upper central opening **28** has a dimension to accommodate the insertion of the fuel
20 cartridge **34** and the basket **38** inside the receptacle **22**. It will also be appreciated that the clasps **46** may be replaced by other closure means for quickly and easily removing the annular cap **44**, for replacing a spent fuel cartridge for example.

Upon the annular cap **44**, there is provided a bellows **48** having an interior
25 region communicating with the receptacle **22** such that the expansion and

retraction of the bellows are relative to the pressure inside the receptacle. Atop the bellows **48**, there is provided a timer mechanism **50**, the operation of which will be described later. In the hydrogen generator according to the preferred embodiment **20**, the gas handling manifold **40** is affixed to the upper portion of the vertical tube **36** above the timer mechanism **50**.

The annular cap **44**, the bellows **48**, the timer mechanism **50** and the gas handling manifold **40** define with the receptacle **22** a closed space for containing and controlling the hydrogen gas being generated inside the receptacle **22**.

A burner plate **60** is mounted over the gas handling manifold **40**. The gas handling manifold **40** has conduit means communicating with the burner plate **60**. A series of orifices are provided in the burner plate **60** to allow the burning of hydrogen gas for cooking food for example in a similar manner as is known of gas stoves. Although the illustrations show a side view of the burner plate **60** it will be appreciated that the burner plate **60** is preferably a circular plate similar to those mounted on common gas stoves.

The gas handling manifold **40** also has a selector valve **62** and a gas outlet fitting **64** communicating with the selector valve **62**. The selector valve **62** is operable for selectively directing the hydrogen gas to the burner plate **60** or to the outlet fitting **64**.

A flexible hose for example, as represented by dash lines **66**, can be connected to the outlet fitting **64** and to a gas appliance such as a lantern **68** to conveniently use the hydrogen gas, or to a gas reservoir **70** for accumulating the hydrogen gas for later use. The appliance may have a

water filter 72 thereon if needed or a check valve 74 to prevent any backflow of gas into the receptacle 22 at the end of an energy production period.

5 With reference to FIGS. 2 and 14, it will be appreciated that a typical energy production period is known to have a heating phase 'A' during which the temperature inside the receptacle 22 rises; an active phase 'B' during which the temperature inside the receptacle 22 is preferably kept at around 85° C, and a cooling phase 'C' during which the reaction gradually stops. At an operation temperature 'T' during the active phase 'B' of
10 about 85° C, the reaction has been found to be self-sustained and the hydrogen gas produced contained minimum water vapours.

The heating phase 'A' can be shortened by introducing a fuel pellet 80 inside the receptacle 22, through the fill opening 24. The fuel pellet 80 preferably contains very fine aluminum particles such as saw dust and
15 filings for examples, compressed with waste paper bits that are impregnated with sodium hydroxide in a dry form. The small aluminum particles of the pellet 80 are known to be highly reactive with water to generate a burst of heat which causes the water temperature to approach the ideal temperature 'T' quickly, and to accelerate a reaction of the water
20 with the larger fuel cartridge 34. Another fuel pellet 80 may also be introduced in the receptacle during the cooling phase 'C' to prolong the duration of an energy production period.

For example purposes, a fuel cartridge 34 having a volume of about one litre, that is about 500 ml of aluminum and about 500 ml of paper filler
25 material impregnated with sodium hydroxide in a dry form, immersed in 10 litres of water is believed to be sufficient for producing heat and

maintaining a reaction for about two hours, in which the active phase is about one hour, and the heating and cooling phases are about one-half hour each. It is believed that the amount of hydrogen gas produced during the active phase 'B' is sufficient for cooking food on the burner plate 60.

5 Referring now to **FIG. 3**, the operation of the bellows 48 is illustrated therein. When the reaction enters its active phase, the heat and pressure generated inside the receptacle 22 rise. The increase in pressure inside the receptacle 22 causes the bellows 48 to expand upward as illustrated in **FIG. 3**.

10 Because the basket 38 and the vertical tube 36 are supported to the gas handling manifold 40, and because the gas handling manifold 40 is affixed to the movable portion of the bellows 48, the expansion of the bellows 34 causes the fuel cartridge 34 to be lifted toward an upper region of the receptacle 22, and by the same doing, causes the water level to fall in the
15 receptacle 22. The contact surface between water and the fuel cartridge 34 is thereby greatly reduced. The reaction is slowed down and the pressure and temperature inside the receptacle 22 are consequently also reduced. As temperature and pressure inside the receptacle 22 are reduced, the bellows 48 collapses to re-immerses the fuel cartridge 34 and to resume the
20 active reaction phase.

Given the structure of the energy production apparatus 20 according to the preferred embodiment, it is believed possible to calibrate the characteristics of the bellows 48 for use with a specific size of receptacle 22 and a specific size of fuel cartridge 34, to precisely control the pressure and temperature
25 of a reaction, such that the apparatus 20 will be practical and safe for use by the general public.

With reference to **FIGS. 4, 8 and 9**, the functions of the timer mechanism **50** of the hydrogen generator **20** will be explained in details. The timer mechanism **50** is provided for further improving the safety of the hydrogen generator **20**. The timer mechanism **50** is used for lifting the fuel cartridge **34** above the water **32** after a set time period, even when the bellows **48** remains in a collapsed mode. The reaction inside the receptacle **22** can thereby be manually stopped or caused to terminate at a set time period by adjusting a knob **90** relative to a dial **92**.

The preferred timer mechanism **50** comprises a coil spring **94** mounted over the vertical tube **36** and an annular spring-abutment plate **96** affixed to the vertical tube **36** above the spring **94** for retaining the vertical tube **36** at a fixed position relative to the upper end of the spring **94**.

The spring **94** is set in a cylindrical pocket **98** extending downward through the timer mechanism **50**. The depth of the pocket **98** is sufficient to accommodate the spring **94** in a compressed form when the timer mechanism is in a latched mode. A seal **100** is affixed to the bottom portion of the pocket **98** around the vertical tube **36**, for allowing a sliding movement of the vertical tube **36** through the timer mechanism **50**, under the action of the spring **94**, and for preventing hydrogen gas from leaking out of the bellows **48**.

One or more latch tabs **102** are movably connected to the timer mechanism **50** and are linked to the operation of the selector knob **90**. When the burner plate **60** is pushed down to immerse the fuel cartridge **34** in water, the latch tabs **102** engage with the annular spring-abutment plate **96** to keep the spring **94** in a compressed state inside the cylindrical pocket **98**.

The linkages, the clockwork and other components mounted inside the timer mechanism **50** have not been illustrated herein for being common to those knowledgeable in latches and locks. In the preferred embodiment, however, the clockwork is a mechanical device not requiring electric
5 power. Also in the preferred embodiment, the latched tabs **102** are in a latching position when the timer knob **90** is set at any time value, and are in an unlatching position when the knob **90** is set at or reaches zero (0) time on the dial **92**.

Referring now to **FIG. 5**, the structure of the burner plate **60** and of the gas
10 handling manifold **40** are explained therein in greater details. The outline of the gas handling manifold **40** is shown in dash lines to simplify the illustration. The gas handling manifold **40** comprises a first set of conduits **110** extending from the vertical tube **36** to the selector valve **62**, to a pressure relief valve **112**, and to a flow control valve **114**; a second set of
15 conduits **116** extending from the selector valve **62** to the burner plate **60**; and a third conduit **118** extending from the selector valve **62** to the outlet fitting **64**.

The burner plate **60** has a plurality of gas orifices **120** therein, and each gas orifice is preferably surrounded by one or more air injection holes **122** to
20 admit oxygen around the gas orifice **120** during the burning of hydrogen gas.

In the preferred embodiment, a minimum amount of hydrogen gas is always directed to the gas orifices **120** to be burnt. The burning of this minimum amount of gas provides a visual indication of the operation of
25 the apparatus **20**, and prevents any accumulation of hydrogen gas in the room in which the apparatus is being used. For this purpose, a flow

control valve **114** is provided in the gas handling manifold **40**, and has a fourth conduit **124** bypassing the selector valve **62**. Therefore, when the selector valve **62** is set to direct the hydrogen gas to the outlet fitting **64**, a minimum amount of gas is still allowed through the flow control valve **114** and to the gas orifices **120** of the burner plate **60**.

The flow control valve **114** is preferably an adjustable type such that it can be opened fully to bypass both the selector valve **62** and the pressure relief valve **112**, to obtain a larger flame **126** at the centre of the burner plate **60** if needed.

The pressure relief valve **112** is provided to further improve the safety of the apparatus, as will be understood from the following description. The pressure relief valve **112** monitors the pressure inside the vertical tube **36** and releases a pressure over an unsafe level, to a whistle **128** which has an outlet opening positioned near one of the gas orifices **120**. The gas flowing from the whistle **128** may thereby be readily ignited by the flame above that orifice **120**, to provide a visual indication of an abnormal operation of the apparatus. The sound of the whistle **128** is yet another sign to alert a user of an over pressure inside the receptacle **22**, and to urge that user to set the knob **90** to zero time to cause the timer mechanism **50** to raise the fuel cartridge **34** out of the water.

As illustrated in **FIG. 6**, the burner plate **60** preferably has a pair of handles **130** affixed thereto to manipulate the upper portion of the apparatus **20** when the clasps **46** are released and the basket **38** is lifted out of the receptacle **22**.

In the preferred apparatus, a gas filter 132 may also be installed over the gas admitting holes 42, for preventing any accumulation of reaction byproducts inside the vertical tube 36. In other embodiments, the vertical tube 36 may be filled with an appropriate granular filtering medium for example for preventing reaction byproducts from reaching the gas handling manifold 40.

As will be appreciated, a pressure gauge 134, a temperature gauge or both, may also be provided on the annular cap 44 or at another convenient location allowing a communication with the receptacle 22, for visually monitoring the development of a reaction occurring inside the apparatus.

In FIG. 7, the burner plate 60 is shown supporting a heat storage device 140, for storing heat during the operation of the apparatus 20. The heat storage device 140 is used for prolonging the beneficial effect of an energy production period when the apparatus 20 is used to heat a camp in the wilderness, or a household during a power outage period for example. The preferred heat storage device 140 comprises a copper plate 142, supported on legs 144, above the burner plate 60, and a perforated dome-shape enclosure 146 enclosing one or more rocks 148 laid over the upper portion of the copper plate 142. The heat storage device 140 is removable from the burner plate 60 and is preferably used whenever the burner plate 60 is not used for cooking food. Further, the receptacle 22 is preferably made of steel or similar heat conductive material for radiating heat during the entire energy production period.

In the preferred embodiment, the inside diameter of the bellows 48 is sufficiently large, 15-25 cm for example, and the spring 94 is calibrated such that the weight of the heat storage device 140 or the weight of a

common cooking pot (not shown) which may be set on the burner plate **60** does not significantly affect the operation of the bellows **48** or of the timer mechanism **50**.

Referring now to **FIGS. 10-13**, several arrangements are proposed for preparing the fuel elements required for use in the hydrogen generator **20** according to the preferred embodiment. The fuel bundle **34** is preferably prepared by overlaying a thin strip of aluminum **150** over a sheet of embossed paper **152** impregnated with sodium hydroxide in a dry form. The aluminum sheet and the paper layer are coiled together to form a cylindrical shape. The preferred cartridge **34** is loosely coiled such that water may be readily absorbed between the layers of the cartridge. The advantage of a loosely coiled cartridge **34** is that the water is allowed to seep into the entire cartridge at once to create an intense reaction, and reduce the duration of the heating phase 'A' of the reaction as illustrated in **FIG. 14**.

Another advantage of the cartridge **34** as described above is that when the layers of the coil are set vertically, the hydrogen gas generated between the layers rises up and creates a vacuum between the layers at the lower end of the cartridge **34** to admit more water from the lower end of the cartridge. This phenomenon is advantageous for wetting the aluminum strip quickly, entirely and continuously.

The preferred fuel cartridge **34** is packaged in a sealed envelope that has an indication as to its duration, potential heat energy and volume of hydrogen gas to be produced by it.

Although the fuel cartridge **34** may be better manufactured with virgin material, it will be appreciated that there are numerous economical and environmental advantages in the manufacturing of fuel elements from waste materials. Accordingly, another preferred fuel unit **160** having a
5 loose content in a bag-like envelope is illustrated in **FIG. 11**. The envelope **162** is water-permeable, and the loose content comprises aluminum turning, aluminum saw dust and filings, aluminum shreds and other aluminum waste particles **164** as normally found in a metal working shop, or as available from scrap metal vendors.

10 It is also possible to use aluminum shreds from domestic waste containers. When the waste aluminum is obtained by shredding food or drink containers for example, the waste material is preferably pre-treated to at least partly remove a protective coating on this aluminum material.

The loose content of the fuel unit **160** also comprises waste paper bits **166**
15 impregnated with sodium hydroxide and dried. The paper bits **166** are made of waste newsprint or similar recyclable paper waste. The paper bits **166** preferably have sizes and quantities similar to the aluminum particles, and are mixed with the aluminum particles **164**. The presence of the paper bits **166** prevents the fusion of the aluminum particles **164** together and
20 ensures a continuous absorption of water throughout the loose content of the fuel unit **160**. The fuel unit **160** is also preferably manufactured and labelled as to indicate its expected energy production period.

The fuel pellet **80** as illustrated in **FIGS. 2** and **12**, and as previously
25 described contains very fine aluminum particles such as saw dust and filings for example, to provide a better water contact and a more intense reaction. One or two fuel pellets **80** are preferably packaged in a

sealed envelope and distributed as reaction accelerators with each fuel cartridge **34**, or with each fuel unit **160** sold.

A third preferred arrangement for a fuel element usable in the apparatus **20** according to the preferred embodiment is illustrated in **FIG. 13**. The fuel measure **170** is preferably comprised of a perforated container **172** filled with aluminum waste **164** and paper bits **166** as previously described.

When the energy production apparatus according to the preferred embodiment **20** is used by someone having access to aluminum waste material, and who does not want to depend on purchased fuel elements, the fuel measure **170** described herein is recommended and is preferably used with a nominal quantity of sodium hydroxide **174** set over the fuel measure **170**. The sodium hydroxide **174** may be compressed into a tablet form as illustrated for easy handling and storage. It may be used in a powder form contained in a water-permeable sachet (not shown), or may be kept in a sealed container and sprinkled generously over the water **32** before introducing the fuel measure **170** into the water **32**.

As to the manner of manufacture of the preferred apparatus and carrying the catalytic reaction, the same should be apparent from the above description and accompanying drawings, and accordingly further discussion relative to this aspect would be considered repetitious and is not provided.

Referring now to **FIGS. 15** and **16**, an industrial application of the hydrogen gas generator according to the present invention will be described. It has been observed that when the hydrogen gas produced by the apparatus is bubbled through an hydrocarbon fuel, the combustion

efficiency of this fuel is greatly improved. Although this phenomenon is not fully understood, it is believed that the hydrogen molecules tend to join hydrocarbon chains within the fuel and form new and shorter hydrocarbon chains or increase the abundance of the shorter hydrocarbon chains. It is known that the shorter hydrocarbon chains are generally more flammable, and burn more efficiently with less pollution.

The apparatus according to the preferred embodiment **20** is portable and can be used advantageously for example to inject hydrogen gas into a fuel line **200** of an internal combustion engine **202** to hydrogenate this fuel before it reaches the engine. Although a gasoline engine **202** is illustrated in **FIG 15**, it will be appreciated that the same concept applies to diesel engines and to the burners of furnaces and boilers, and virtually any other equipment burning a liquid fossil fuel.

Referring now to **FIG. 16** there is illustrated therein an alternate embodiment **210** of the apparatus of the present invention for use to hydrogenate hydrocarbon fuels for large stationary engines and the burners of boilers. In this alternate embodiment, the fuel **212** is introduced inside the receptacle **214** containing an aqueous solution **216** comprising sodium hydroxide, through a fuel inlet pipe **218**. This fuel floats over the aqueous solution and leaves the receptacle through a fuel outlet pipe **220**. The flow control valves and check valves on the fuel line have not been illustrated for clarity. Also for a better understanding of the invention, the illustration in **FIG. 16** has not been drawn to scale.

Makeup water is added through a makeup water inlet pipe **222** on the fuel inlet pipe **218** or otherwise, to maintain the level **224** of the aqueous solution stable. The level control equipment for maintaining the level of

the aqueous solution stable has not been illustrated for being known to those skilled in the art of hydraulics.

Aluminum particles **226** for the reaction are introduced in the receptacle **216** from a hopper **228** mounted atop the receptacle **214**, then through an
5 airlockTM rotary feeder **230**, and down an aluminum feed pipe **232**. The aluminum feed pipe **232** extends under the level **224** of the aqueous solution and ends immediately above a horizontally-rotating screen disc **234**. The screen disc **234** is supported on an arm **236** and spindle **238**, and is driven by a gear motor **240** mounted to the side of the receptacle **214** and
10 having a shaft and pinion (not shown) extending inside the arm **236** and spindle **238**.

The alumina **242** generated by the reaction is collected at the bottom of the receptacle **214** and is recovered by means of a screw conveyor **244** or otherwise without stopping the reaction.

15 In order to prevent excessive reaction of the aluminum particles with water inside the aluminum feed pipe **232**, a circulation pump **246** and recirculating piping **248** are provided to circulate the aqueous solution from the receptacle and into the aluminum feed pipe **232**, to continuously carry away the aluminum particles **226** from inside the aluminum feed pipe
20 **232** and onto the screen **234**.

The hydrogen gas generated at the screen level bubbles through the layer of fuel **212** for hydrogenating this fuel. The hydrogen gas not absorbed into the fuel **212** is recovered through an outlet valve and fitting **250** on the cover of the receptacle for use in another application. This hydrogen gas
25 is relatively clean of water vapour for having been filtered through the fuel.

This alternate embodiment of a hydrogen gas generator is believed to be particularly useful to improve the combustion characteristics of diesel fuels and bunker CTM oils for stationary installation such as engine-generator sets and large industrial boilers.

5 While two embodiments of an apparatus for producing hydrogen gas and for hydrogenating hydrocarbon fuels have been described herein above, it will be appreciated by those skilled in the art that various modifications, alternate materials, compositions and equivalents may be employed without departing from the true spirit and scope of the invention.

10 Therefore, the above description and illustrations should not be construed as limiting the scope of the invention which is defined by the appended claims.